Slow-Light Dispersion in Periodically Patterned Silicon Microrings

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Abstract:
We demonstrate evanescent coupling between a strip waveguide and a periodically-patterned ring resonator in the slow light regime. Resonances with a group index > 22 are efficiently coupled with an extinction ratio of > 20 dB. This result opens up the possibility of new applications in compact device integration in wavelength-division multiplexing (WDM) systems while reducing the in-band four-wave mixing (FWM) crosstalk.

Summary of Research:
Periodic structures exhibit strong dispersion that enables dense optical device integration. Recently, photonic crystal based waveguides [1] and resonators [2] have been demonstrated as compact delay lines [3] and small-modal volume cavities [4]. Recently, we reported a novel microring resonator structure patterned with periodic circular air holes on a silicon-on-insulator (SOI) platform [5,6]. By taking advantage of the slow light effect near the Brillouin zone edge, the size of the ring resonator can be reduced while still preserving its capacity to support multiple optical channels in wavelength-division multiplexing technology. The non-zero dispersion reduces the in-band FWM crosstalk in a WDM system. However, the impedance mismatch between the highly dispersive resonance modes and the linear dispersive strip waveguide could result in insufficient coupling. We match the phase velocities by tuning the widths of strip waveguide in order to compensate for this effect.

Figure 1(a) shows the top-view scanning electron micrograph (SEM) of a fabricated device. The devices are fabricated on SOI wafers with a 3 µm buried oxide layer and a thin silicon layer 250 nm thick. Patterns are defined by electron beam lithography with negative-tone HSQ photoresist. The silicon layer is etched by an ICP-RIE etcher with chlorine gas. The periodicity of the air holes is a = 450 nm. There are 100 circular air holes on the ring with hole radius of 0.3a. The width of the ring is 1.00a. The periodically-patterned microring is coupled evanescently to a straight strip waveguide. We measure the transmission spectra by using a wavelength scanning technique. From the measured transmission spectra [6], we estimate the highest group index of ~ 20, and Q ~ 1,000. The slow-light modes are critically coupled with high extinction ratio of > 20 dB. The Q-factor is mainly limited by the scattering losses induced by the interface roughness and the disordering of the periodic structure.

References:
Figure 1: Scanning electron micrograph of a fabricated microring resonator with 100 periodic circular holes (top), and magnified micrograph of the evanescent coupling region with strip waveguide width \( w \) (bottom).